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Tools and Methods for enabling senior design classes during the COVID19 pandemic and their application to future challenges

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Bio – Stavros Kalafatis Stavros Kalafatis studied in Canada and England and obtained by BSc in Electrical and Computer Engineering at Surrey. He completed his MSc degree in Computer Engineering at the University of Arizona. He joined Intel in 1991 as a design engineer and architect in the Pentium-Pro and eventually become the Senior Director responsible for the development of Gen IV and V Intel desktop processors, leading large teams of engineers whose efforts resulted in revenues exceeding $5 Billion. He then moved to direct new business initiatives for Intel in the dense server space resulting in businesses with a net present value of $600 Million. Stavros holds 11 patents in the field of CPU computer architecture. In 2016 he joined the faculty at the Electrical and Computer Engineering (ECE) department at Texas A&M University as a Professor of Practice where he was appointed Director of the Capstone program. He was the ECE ABET representative for 2 years and was appointed co-Associate Department Head in 2019. He has been a Texas A&M Maroon and White Leadership coach since 2017 and won the coach of the year award in 2021. Since joining Texas A&M University, he has published 6 papers and has 2 pending submission. His research interests lie in: AR, VR solutions, Robotics, High performance computing and networking and AI applications in Agriculture.

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Abstract

Engineering curricula across the United States seek to develop well-rounded engineers with the ability to solve real problems upon graduation. To that end, capstone/senior design classes are present in most if not all ABET accredited undergraduate engineering programs. As the goal is to expose students to the tools they will need to solve actual problems, these classes are centered around team projects in a laboratory setting, with some lecture delivery in a supporting function. Physical distancing rules, as well as reduced/remote access of laboratories and equipment during the COVID-19 pandemic, posed significant challenges to the continued delivery and greatly hindered achievement of the stated educational outcomes of these classes. A southwestern institution developed new and creative strategies to address these challenges while continuing to operate under these constraints. Some were temporary, while others led to discoveries that modified the class delivery in the long term thus benefiting both students and instructors. In this paper we will describe the challenges we faced and the solutions we came up within the Electrical and Computer Engineering Department, as well as the student reaction to the COVID-19 laboratory experience. The learnings from the affected 2019 - 2021 capstones provide an opportunity to both apply methods to normal, post-pandemic instruction and to be prepared for potential future interruption of capstone team-based laboratories.

Background

While flipped classroom approaches have been studied extensively portraying a generally positive potential impact to the student population (Bergman and Sams 2012) [1], their application during a forced external event like a pandemic has been very limited. The 1918 flu pandemic led to school closures driven by a need to both curtail the spread of the virus but more so by the limitations posed by teacher absenteeism. The remote classroom tools available in the 21st century was not present then, so the actions were significantly different. The most recent time that educational institutions had to act to address a significant pandemic was the swine flu/H1n. In Ruben A. Proano (2016) [2], RIT put together a task force that worked to address (1) campus hygiene, (2) medicine and vaccine procurement, (3) confinement of infected students (4) public relations, (5) capacity planning of the medical center, (6) class disruption, (7) food and wastage logistics during the pandemic, and (8) class suspension. While these were excellent items to be addressed, the classroom delivery and maintenance of educational quality were not addressed in great detail. So, when the 2019 COVID-19 pandemic CDC guidelines came into effect, higher education institutions were largely unprepared. Flipped Classroom formats (FC) did provide a significant relief as per Campillo-Ferrer et al (2021) [3], but student feedback was mixed. Most importantly, studies of classroom impact by Dhawan (2020)[4] and Fatani (2020) [5] focused on non-engineering disciplines, where the presence of laboratories is limited. This left the question about the impact of the pandemic actions on engineering students open.

The COVID-19 pandemic impact

The spring 2020 semester (starting in January 2020) seemed like it would be like any other. The capstone class at our South-Central Institution was fully enrolled and students attended their laboratories where they would work on their projects eight times per week. All that suddenly changed after spring break 2020 (mid-March) at which point the Center of Disease Control (CDC) and State physical distancing guidelines were put in place in order to address the spread of the COVID-19 virus. Students attending laboratories would now have to pre-register when they would attend, sit 6 feet apart and ensure that they were in good health (self-reported). The distancing rules meant that most laboratories were working at ⅓ to ½ capacity, since there was not enough space and not enough time slots to increase the number of laboratories. Teaching assistants were also required to physically distance themselves from students, making it very hard to view issues and assist students in resolving them. Unfortunately, the lack of time to plan for an emergency like this one made it impossible to put in place new methods of engagement. Instead, student feedback was collected and plans were developed over the remainder of the semester in order to be implemented in the upcoming semesters, especially the fall 2020 semester which has the largest enrollment.

Actions in response to constraints

In response to the health guidelines imposed by the COVID-19 pandemic, we took the following key actions for the Electrical and Computer Engineering (ECE) laboratory classes: change laboratory occupancy and duration; modify the types of projects offered and offer lectures online instead of in person. Below we will describe each of these strategies and share feedback collected from our student population that consisted of 318 students, enrolled in a two semester capstone course working on 108 projects.

1) **Change laboratory occupancy and duration**

Implementing CDC and university physical distancing rules led to significant laboratory occupancy reduction (Table 1). In order to enable students to get some time in the laboratory, the 50-64-person labs were split into 3 - 50-minute cohorts of 11 students each, which enabled each student to get access to the laboratory every 2 weeks.

Fall 2019 (pre-COVID)	50-64 students/lab	3 hr. lab	22 benches	2-3 students/bench
Fall 2020 (COVID)	8-12 students/lab	3 - 50-minute labs + 10 min sanitization	12 physically spaced benches	1 student per bench

Table 1: ECE Capstone Physical distancing occupancy changes to meet COVID restrictions

2) Modify types of projects

Senior electrical engineers and computer engineers within the Department of Electrical and Computer Engineering are required to complete a two-semester capstone sequence. Capstone is team-based design on the same project for both semesters. To accommodate the skills of both electrical and computer engineers, traditionally, 10-20% of capstone projects are fully software systems. Approximately 5% of projects are exclusively hardware design. The remaining projects are a mixture of software and hardware development.

Like other institutions, (Kubelik 2021 [6], Kathir 2021 [7]), with the onset of COVID-19 control actions, we determined that software projects did not require physical access to the laboratory and thus could proceed as normal. The remaining projects were divided into (1) projects for which physical access to specialized test equipment, fabrication materials and tools, and/or large or complex components or safety constraints (e.g. systems involving AC power and water) which needed physical lab access, and (2) projects which could be assembled and tested by students at home. Capstone team members were required to have laptop computers and the majority of students possessed cell phones with cameras, phone-chargers, displays, and usually a Digilent Analog Discovery II, a low-cost electronics test tool used in several courses in the student's curricula. Teams were allowed to spend their team capstone budget on enhancing their at-home design and testing capabilities.

Tables 2 and 3 show that the percentage of software projects increased in both fall 2020 and spring of 2021 compared to the previous year. During fall 2020, the largest fraction of projects was test at home. We believe this was a result of a combination of student concerns about COVID-19 and uncertainty on the part of faculty as to whether physical access to the lab could be maintained in the face of changing COVID-19 exposure and infection rates.

	Fall 2019	(Pre-Covid)	Fall 2020	(Covid)
Total Students	199		246	
No. of Teams	60		70	
Avg. Team Size	3.3		3.5	
Software Projects	8	13%	22	31%
At-home build/test projects	n/a	n/a	26	37%
In-lab build/test projects	52	87%	22	31%

Table 2: ECE Capstone Project size and scope changes (Fall Semester 2019 vs 2020)

By the spring of 2021, students were more accustomed to COVID-19 precautions and actions. With changing expectations from students and the faculty learning from the previous semester on

managing in-person laboratories with COVID-19 restrictions, the project types began to approach pre-COVID-19 distributions.

	Spring 2020	(Pre-Covid)	Spring 2021	(Covid)
Total Students	91		132	
No. of Teams	26		37	
Avg. Team Size	3.		3.6	
Software Projects	5	19%	8	21%
At-home build/test projects	n/a	n/a	10	27%
In-lab build/test projects	21	81%	19	52%

Table 3: ECE Capstone Project size and scope changes (Spring Semester 2020 vs 2021)

3) Offer lectures online instead of in person

Capstone lectures focus on project management techniques as well as common design and implementation pitfalls, with a goal to enable students to execute their projects more efficiently and with fewer in laboratory accidents or device damages. Under COVID-19 restrictions all lectures were moved to an online synchronous format where the instructor would deliver the information to the students via an online ZOOM meeting. All lectures were recorded so that students could access them at any time and auto-graded quizzes were used to ensure that students retained the material taught.

Learnings and data from students

Student use of in-person laboratories:

In fall of 2020, with cohort-based laboratory policies, greater focus on software projects and at-home design/test projects, 45 students (52% of the population) at the beginning of the semester requested to participate in the 2nd semester capstone laboratory remotely. University policy allowed students to decide between remote and in-person for each laboratory.

The feedback from the students in fall 2020 (Figure 1) clearly illustrates that while the attempt to enable in person access was impactful, the actual lab access was significantly reduced.

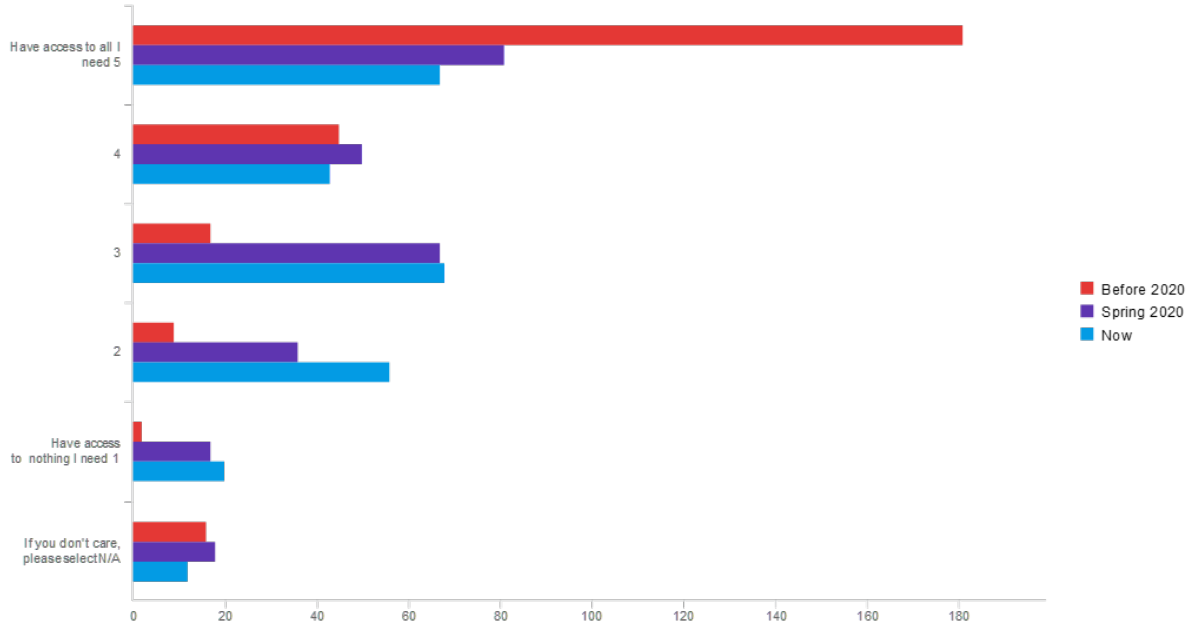

Figure 1: student lab access pre-COVID vs post-COVID restrictions (data collected fall 2020)

Students tended to favor remote participation more than their remote vs in-person registration decisions indicated. 16 students were assigned software projects, 31 assigned at home design/test projects, and 39 assigned in-lab design/test projects. Figure 2 shows that as the semester progressed, weekly in-lab participation early in the semester was significantly below the registration for remote lab rate and below the fraction of students assigned to in-laboratory projects. Note that many tasks associated with in-lab projects did not require access to laboratory equipment or project hardware and thus students could accomplish even these tasks remotely. As the semester progressed, and project activities focused on integration of systems and final assembly, test, and validation, the laboratory usage rose significantly and remained relatively constant week-to-week for both number of students using the lab and average time per student spent in the lab.

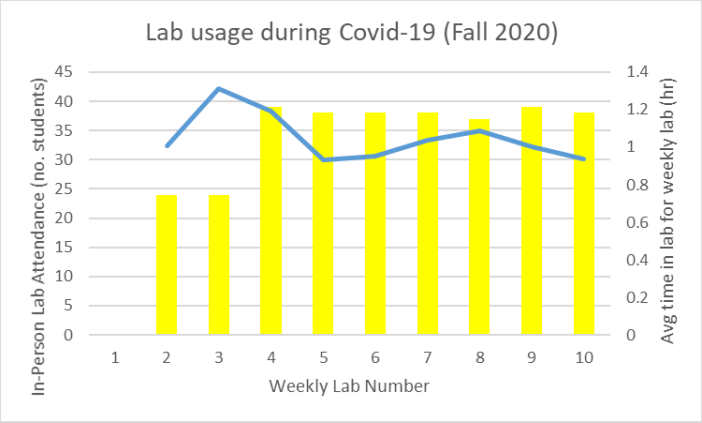

Figure 2: student lab usage during Covid (data collected Fall 2020)

With respect to ability to use and well as access to equipment needed for remote teaching (i.e. laptop, camera, remote proctoring software etc.) students indicated that they have a good understanding of what is needed, but nevertheless, accessibility in some cases was limited (Figures 3 and 4).

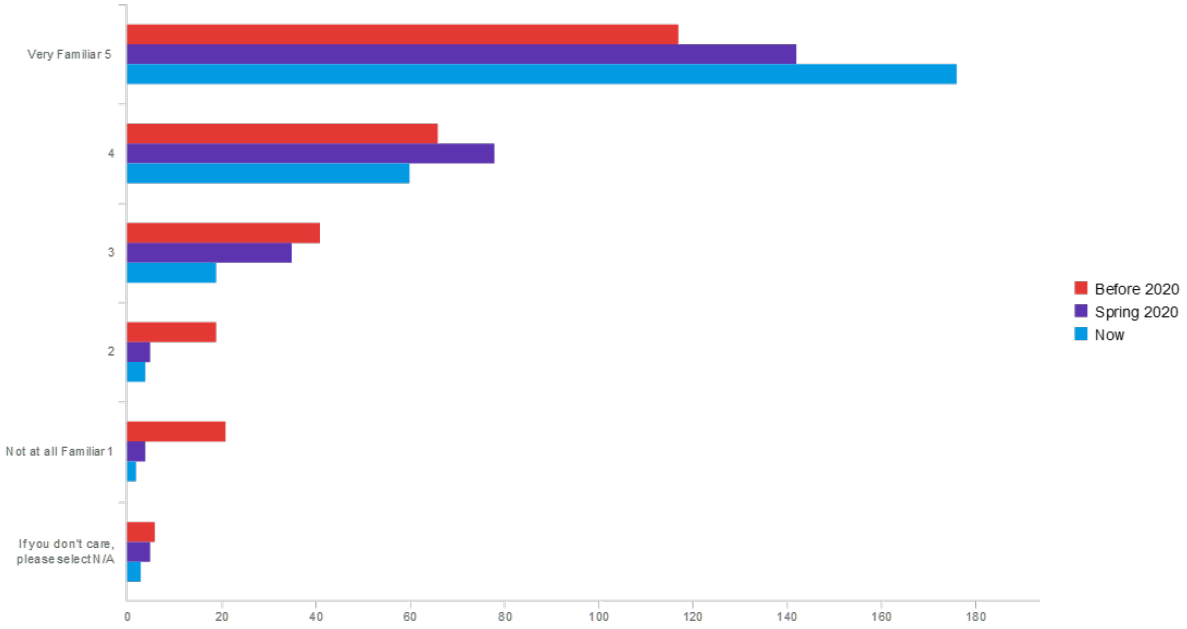

Figure 3: Familiarity with remote classroom technology

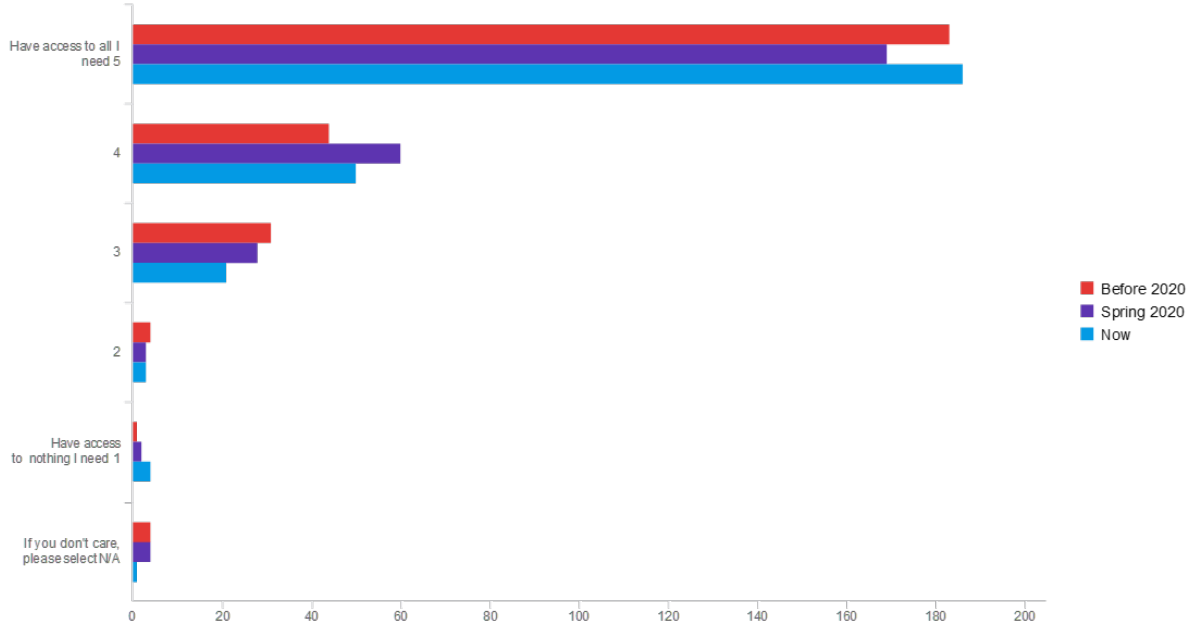

Figure 4: Access to technology for remote learning

Furthermore, access to faculty (due to lack of in person classes and well as remote office hours) was identified as non-optimal (Figure 5).

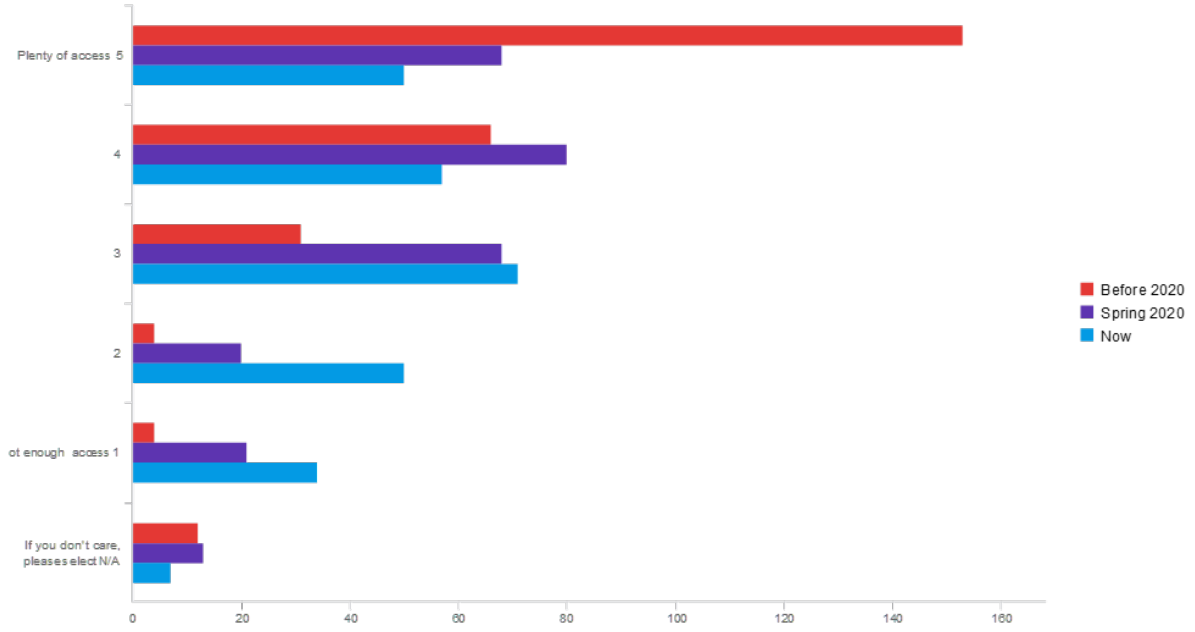

Figure 5: Access to faculty during COVID-19

The compounding effect of non-optimal lab usage, limited access to faculty for support and technology challenges led to 63% of students (Figure 6) indicating that the switching over to a

hybrid/online format had severely adversely affected their learning experience. Students were adamant (72.5%) that return to F2F format would resolve most of the challenges they were facing (Figure 7).

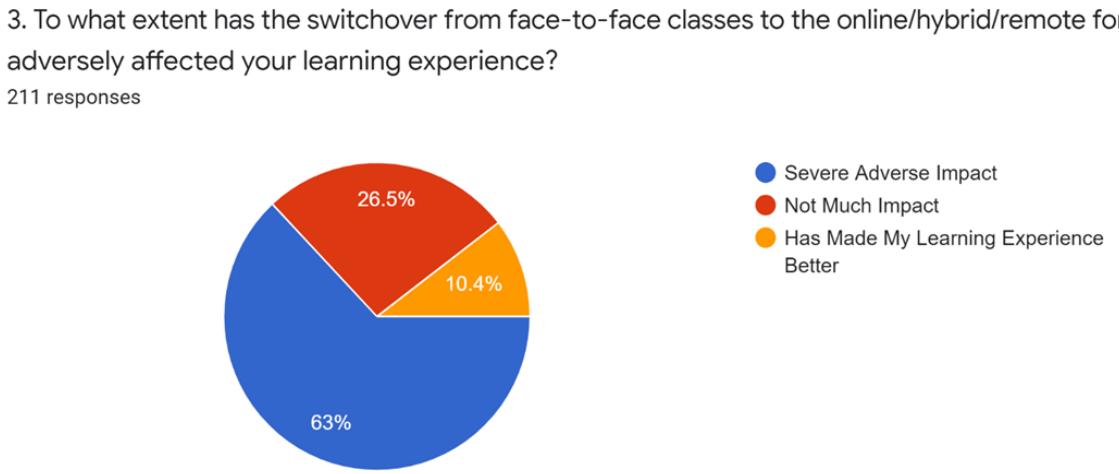

Figure 6: Student feedback of impact of online laboratories and lectures

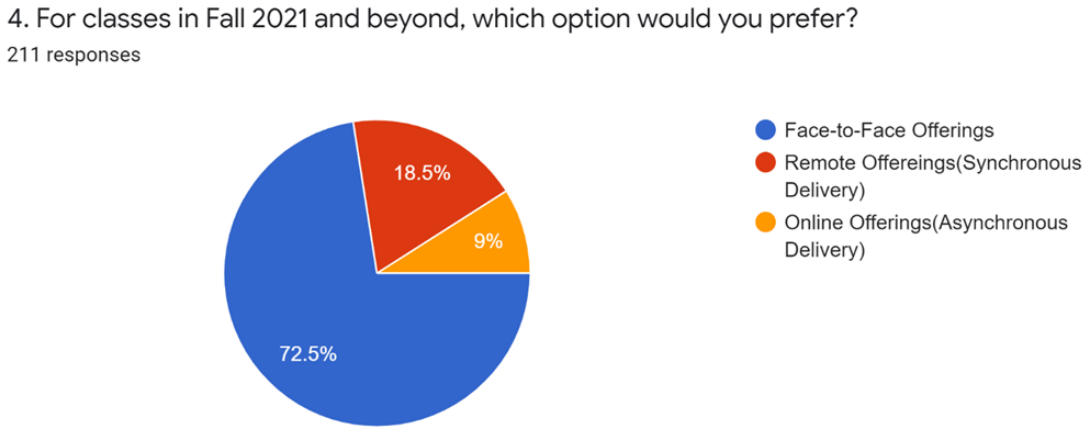

Figure 7: Student feedback on class format

To this end starting in fall 2021, all classes were offered in a F2F format and students enrolled in person. COVID-19 related absences were still present, and masks were strongly encouraged both in the classroom as well as the laboratories. Student feedback was overwhelmingly positive on the actions taken (Figure 8).

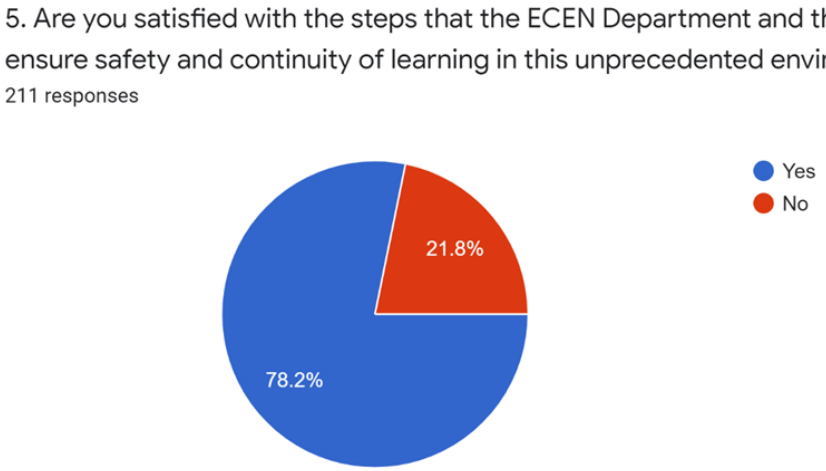

Figure 8: student feedback on plans put in place by the ECE department and University during COVID-19

Conclusions

COVID-19 presented a very unique challenge to all educational institutions and was particularly impactful to classes that had laboratories, such as the Electrical and Computer Engineering department at our south-central university. In response to unprecedented conditions, a three-pronged approach was taken: 1) change laboratory occupancy and duration, 2) modify the types of projects offered, and 3) offer lectures online instead of in person. This approach enabled laboratories for the capstone/senior design class to continue, enabling students to learn and graduate in a timely fashion. Nevertheless, the student's feedback, while applauding the efforts put in place clearly indicated that in person learning was significantly better, providing a learning experience that the remote environment could not replicate.

This leaves room for improvement for remote laboratory classes. While project types will continue to enable remote work (something the student body appreciated), remote access to measuring equipment is for example an area that could be improved upon. Hybrid lecture format did see support from ~25% of students, which indicates that it can be successful and it needs to improve especially on the motivational and student-student interaction side.

In summary, several of the actions taken to address the COVID-19 pandemic restrictions will continue to be implemented in the capstone/senior design class, while others will need to be improved on over time so that future emergencies still allow a positive learning environment, even when forced to not be F2F.

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